# Institute for Materials Science

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## IMS Rapid Response 2016 * Phase II Recipient Seminar

**Dr. Ron Klueh**
**Metallurgical Consultant**

## Swelling of Ferritic/Martensitic Steels: Effect of Microstructure

**Tuesday, October 4, 2016**
**8:30 - 9:30 am**
**MSL Auditorium (TA-03 - Bldg 1698 - Room A103)**

**Abstract:** Ferritic/martensitic steels are preferred over austenitic stainless steels for nuclear applications because of their exceptional swelling resistance and thermal properties. In a Journal of Nuclear Materials paper in 2000, Garner, Toloczko, and Sencer (GTS) took issue with the "conventional wisdom" of superior swelling resistance of the ferritic/martensitic steels and concluded they had a much higher swelling rate than previously reported.

The GTS theory is based on crystal structure and does not depend on microstructure. In developing the theory from observations on simple ferritic alloys, GTS ignored investigations on several heats of the ferritic/martensitic steel HT9 that had superior swelling resistance with low steady-state swelling rates. Data from those studies showed considerable variation in swelling for different heats and heat treatments. The origin of the variation has not been explained.

Garner recently used the GTS analysis to cast doubt on the superior swelling behavior of HT9 by presenting ion-irradiation data showing HT9 behaves according to the GTS hypothesis.

The objective of the proposed presentation is:

* Demonstrate the difference between the complicated microstructure of ferritic/martensitic steels and the simple microstructures of alloys cited by GTS to support their hypothesis.
* Describe an analysis of literature data from swelling studies on HT9 that contradicts the GTS hypothesis and demonstrates how microstructural effects explain the variation in swelling properties observed in those studies.
* Show how the HT9 microstructure leads to an explanation for variation of swelling resistance for different heats and different heat treatments.
* Present an equation that describes the effect of microstructure on swelling behavior of HT9 and other ferritic/martensitic steels.
* Apply the equation to Garner's recent ion-irradiation results for HT9, explain how microstructure is the reason for the observed behavior, and demonstrate the irrelevance of the observations to properly heat treated (normalized-and-tempered) ferritic/martensitic steels.
* Discuss the implications of detailed observations on microstructure and the equation for (1) development of F/M steels with improved radiation resistance, (2) development of swelling and hardening models, (3) swelling calculations from TEM observations, and (4) effect on properties other than swelling (e.g., irradiation creep, thermal creep, etc.).

**Bio:** Dr. Ronald L. Klueh obtained BS in Metallurgical Engineering from Purdue University, MS in Metallurgical Engineering from Carnegie Mellon University, and PhD from Carnegie Mellon University in Metallurgy and Material Science.

He was a senior research staff member of the Metals and Ceramics Division of the Oak Ridge National Laboratory (ORNL) until 2008. At ORNL, he conducted research on the physical metallurgy, corrosion and compatibility behavior, and mechanical properties of various metals and alloys. Beginning in 1980, his work was concentrated on development and testing of ferritic and martensitic steels for conventional power plants and nuclear fission and fusion reactors along with radiation-damage studies of these steels. He co-authored the book High Chromium Ferritic and Martensitic Steels for Nuclear Applications published by ASME. He also authored and co-authored over 250 papers in international scientific journals and over 60 ORNL reports, and made over 180 scientific presentations at international conferences.

Since leaving ORNL, he has worked as a materials consultant with TerraPower LLC and Elysium Industries.

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